

**RAPID CYCLE PRESSURE SWING ADSORPTION OXYGEN
CONCENTRATION METHOD AND MECHANICAL VALVE FOR THE
SAME**

4 BACKGROUND OF THE INVENTION

5 1. Field of the Invention

6 The present invention relates to a rapid cycle pressure swing adsorption
7 oxygen concentration method, and more particularly to an oxygen concentration
8 method that uses a cam-actuated mechanical valve to control flow of gases,
9 timing of pressurization and pressure conditions to improve efficiency of
10 producing concentrated oxygen from air.

11 2. Description of Related Art

12 Oxygen concentrators have been considered a particularly cost effective
13 and preferred apparatus to supply concentrated oxygen for supplemental oxygen
14 therapy and for patients with respiratory disease at homes or hospitals. Over the
15 last few years, the oxygen concentrators have been extended to provide the
16 concentrated oxygen for beauty treatment, air conditioning machines and
17 welding industries.

18 Pressure swing adsorption (PSA) is a process for separating gasses from
19 gas mixture, such as air. The pressure swing adsorption process is now well
20 known as a very effective way to produce concentrated oxygen from the air. In a
21 pressure swing adsorption process, the ambient air is pumped into a sieve tank
22 that is typically fabricated of an airtight container filled with a molecular sieve
23 material, such as Zeolite. For the separation of individual gasses in the air, the
24 pressure conditions in the sieve tank should be controlled precisely. However, in

1 a conventional way to control the pressure conditions in the sieve tank,
2 electromagnetic valves or other types of valves, such as rotatory valves have
3 been widely used for fluid control of the air to switch the pressure conditions in
4 the sieve tank.

5 However, when a pressure swing adsorption oxygen concentrator uses
6 the electromagnetic valves to switch and control the airflow in the sieve tank, the
7 flow rate and direction of the pumped air will be changed which causes noise as
8 fluid is processed. Besides, the timing of pressurization cannot be controlled
9 precisely that lowers efficiency of producing concentrated oxygen. For a high-
10 end oxygen concentrator, high quality and performance are generally the focus
11 and requirement of users. The conventional method that uses the
12 electromagnetic valves to switch the pressure conditions for the pressure swing
13 adsorption oxygen concentration will cause undesirable noise and low
14 performance in the oxygen concentrator.

15 To overcome the shortcomings, the present invention provides a rapid
16 cycle pressure swing adsorption oxygen concentration method that uses cam-
17 actuated valves to control flow of fluid to mitigate or obviate the aforementioned
18 problems.

19 **SUMMARY OF THE INVENTION**

20 The main objective of the invention is to provide a rapid cycle pressure
21 swing adsorption oxygen concentration method to efficiently concentrate
22 oxygen from the compressed air, and the method uses a mechanical valve having
23 at least one cam-actuated valve to control airflow of the air.

24 Another objective of the present invention is to provide a mechanical

1 valve for the pressure swing adsorption oxygen concentration method to
2 improve oxygen concentration performance.

3 Other objectives, advantages and novel features of the invention will
4 become more apparent from the following detailed description when taken in
5 conjunction with the accompanying drawings.

6 **BRIEF DESCRIPTION OF THE DRAWINGS**

7 Fig. 1 is a perspective view of an oxygen concentrator having a
8 mechanical valve in accordance with the present invention;

9 Fig. 2 is a timing diagram of the mechanical valve of the embodiment in
10 Fig. 1, indicating the pressure conditions and timing;

11 Fig. 3 is a schematic flow diagram of the oxygen concentrator,
12 illustrating particularly a flow direction of fluid as multiple actuating cams of the
13 mechanical valve are rotated at angle of 90° from an initial angular position;

14 Fig. 4 is a schematic flow diagram of the oxygen concentrator,
15 illustrating particularly a flow direction of fluid as the actuating cams of the
16 mechanical valve are rotated at angle of 165° from the initial angular position;

17 Fig. 5 is a schematic flow diagram of the oxygen concentrator,
18 illustrating particularly a flow direction of fluid as the actuating cams of the
19 mechanical valve are rotated at angle of 195° from the initial angular position;

20 Fig. 6 is a schematic flow diagram of the oxygen concentrator,
21 illustrating particularly a flow direction of fluid as the actuating cams of the
22 mechanical valve are rotated at angle of 270° from the initial angular position;

23 Fig. 7 is a schematic flow diagram of the oxygen concentrator,
24 illustrating particularly a flow direction of fluid as the actuating cams of the

1 mechanical valve are rotated at angle of 345° from the initial angular position;
2 and

3 Fig. 8 is a schematic flow diagram of the oxygen concentrator,
4 illustrating particularly a flow direction of fluid as the actuating cams of the
5 mechanical valve are rotated at angle of 15° from the initial angular position.

6 DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

7 A rapid cycle pressure swing adsorption oxygen concentrator in
8 accordance with the present invention uses a mechanical valve that has at least
9 one cam-actuated flow control valve to switch flow of fluid, such as compressed
10 air incoming into a sieve tank of the oxygen concentrator that is fitted with
11 molecular sieve material. With reference to Fig. 1, a preferred embodiment of an
12 oxygen concentrator (not numbered) that embodies the principles of the present
13 invention is shown and illustrated. The oxygen concentrator comprises a
14 mechanical valve (10) and a sieve tank (20).

15 With further reference to Fig. 3, the mechanical valve (10) is embodied
16 to comprise a mounting bracket (11), a covering housing (12), a valve actuator
17 (not shown), throttling valves (137) and five cam-actuated flow control valves
18 including a first valve (131), a second valve (132), a third valve (133), a fourth
19 valve (134) and a fifth valve (135) where the cam-actuated flow control valves
20 and the throttling valves (137) are shown in schematic symbols. Each of the
21 cam-actuated flow control valves can be a 2-position, 2-way air pilot directional
22 control valve having respectively an actuating follower (136) that can be a roller
23 to actuate the flow control valves to open as the followers (136) are pressed. In
24 addition, numbers of the cam-actuated flow control valves in the disclosed

1 embodiment can be modified, and types of the flow control valves can also be
2 modified to embody the principles of the present invention. For example, if only
3 one cam-actuated flow control valve is used, this flow control valve can be a
4 different type of flow control valve that is different from the 2-position 2-way air
5 pilot directional control valve. Such cam-actuated flow control valves are well
6 known in this art, and there is no description provided further.

7 The mounting bracket (11) is mounted on the sieve tank (20) and has an
8 inner space (not numbered), an intake air entrance (101) and an exhausting exit
9 (102). The intake air entrance (101) is adapted to connect to a compressed air
10 source (103), such as an air compressor (not shown) where the compressed air
11 source (103) is shown in schematic symbol in the following drawings. The valve
12 actuator is mounted on the mounting bracket (11) and is implemented with a
13 motor (111), a rotating shaft (112) and five cams (113) corresponding to the
14 cam-actuated flow control valves. The rotor (111) can be a stepping motor (also
15 called stepper motor) and is mounted on the mounting bracket (11). The rotating
16 shaft (112) is mounted in the inner space of the mounting bracket (11), connects
17 to the motor (111) and is rotated by the motor (111). The cams (113) are attached
18 to the rotating shaft (112) and are rotated by the rotating shaft (112) to actuate
19 precisely the corresponding cam-actuated flow control valves (131, 132, 133,
20 134, 135) in order according to a timing diagram illustrated in Fig. 2.

21 The sieve tank (20) is implemented with a first molecular sieve bed (21),
22 a second molecular sieve bed (22) and an oxygen storage bed (23). The first and
23 the second molecular sieve beds (21, 22) respectively communicate with the
24 oxygen storage bed (23) by means of channels (not numbered). Both the first

1 and the second molecular sieve beds (21, 22) are filled with molecular sieve
2 materials (not shown). The oxygen storage bed (23) has a concentrated oxygen
3 outlet tubing (231) so that the concentrated oxygen can flow out of the oxygen
4 storage bed (23) to provide the oxygen for persons who need it.

5 In order to control the flow of the compressed air and the pressure
6 conditions in the three beds (21, 22, 23), the cam-actuated flow control valves
7 (131, 132, 133, 134, 135), the intake air entrance (101) and the exhausting exit
8 (102) are respectively connected to the beds (21, 22, 23) and the compressed air
9 source (103) by means of different channels (not numbered) in a manner as
10 described below.

11 The intake air entrance (101) connects to the compressed air source (103)
12 to permit the compressed air to enter either the first or the second molecular sieve
13 beds (21, 22) of the sieve tank (20). The first valve (131) interconnects the first
14 molecular sieve bed (21) with the exhausting exit (102) to control the flow of
15 exhausting air out of the first molecular sieve bed (21). The second valve (132)
16 interconnects the intake air entrance (101) with the first molecular sieve bed (21)
17 to control the flow of incoming compressed air into the first molecular bed (21).
18 The third valve (133) interconnects the first molecular sieve bed (21) with the
19 second molecular sieve bed (22) to control the flow of air entering into one from
20 another. The fourth valve (134) interconnects the intake air entrance (101) with
21 the second molecular sieve bed (22) to control the flow of incoming compressed
22 air entering into the second molecular sieve bed (22). Finally, the fifth valve (135)
23 interconnects the second molecular sieve bed (22) with the exhausting exit (102)
24 to control the flow of exhausting air out of the second molecular sieve bed (22).

1 With reference to Figs. 2 and 3, the motor (111) starts to rotate the cams
2 (113) at a constant speed whereby the cams (113) are rotated at angle of 90° from
3 an initial angular position, and the pressure conditions in the molecular sieve
4 beds (21, 22) and the oxygen storage bed (23) are changed and indicated by a
5 line 3 shown in Fig. 2. At this moment, the actuating followers (136) of the
6 second and the fifth valves (132, 135) are respectively actuated by the
7 corresponding cams (113) to switch the two aforesaid valves (132, 135) to open.
8 The compressed air comes into the first molecular sieve bed (21) via the intake
9 air entrance (101) and through the opened second valve (132) to pressurize the
10 first molecular sieve bed (21). Nitrogen of the incoming compressed air is
11 trapped by the molecular sieve material in the first molecular sieve bed (21)
12 while oxygen of the compressed air is allowed to flow through. The purified
13 oxygen will eventually go into the oxygen storage bed (23) through the throttling
14 valve (137) between the two beds (21, 23). The first molecular sieve bed (21) is
15 now maintained in a so-called “adsorption phase” that separates the oxygen from
16 the compressed air to produce an oxygen-rich product stored in the oxygen
17 storage bed (23).

18 Meanwhile, the fifth valve (135) is also opened. The pressure in the
19 second molecular sieve bed (22) will tend to be equalized with atmospheric
20 pressure so that the molecular sieve material in the second molecular sieve bed
21 (22) will release or purge the nitrogen that has been trapped during the previous
22 step. Meanwhile, a small amount of purified oxygen in the oxygen storage bed
23 (23) will come into the second molecular sieve bed (22) through the throttling
24 valve (137) between the two beds (22, 23) to purge and vent the nitrogen to the

1 atmosphere via the exhausting exit (102) because of pressure difference between
2 the two beds (22, 23) and a flow limitation caused by the throttling valve (137).
3 The remained purified oxygen in the oxygen storage bed (23) can be directed to
4 the concentrated oxygen outlet tubing (231) to provide a person concentrated
5 oxygen. At this situation, the second molecular sieve bed (22) is now maintained
6 in a so-called “desorption phase” that the molecular sieve material is revived to
7 have a capability of trapping the nitrogen form the air.

8 With reference to Figs. 2 and 4, in the next step, the cams (113) are now
9 to be continuously rotated at an angle of 165° related to their initial positions,
10 and the pressure conditions in the molecular sieve beds (21, 22) and the oxygen
11 storage bed (23) are indicated by a line 4 shown in Fig. 2. The fifth valve (135) is
12 closed now, and instead, the third valve (133) is opened. The compressed air
13 flows continuously into the first molecular sieve bed (21) to produce rapidly the
14 oxygen-rich product that is stored in the oxygen storage bed (23). Since the
15 pressure in the first molecular sieve bed (21) is much higher than the pressure in
16 the second molecular sieve bed (22), a small amount of the purified oxygen in
17 the first molecular sieve bed (221) will simultaneously direct into the second
18 molecular sieve bed (22) to pressurize the same as the third valve (133) is opened.
19 In this situation, the second molecular sieve bed (22) is maintained in a so-called
20 “balance phase”.

21 The balance phase for the second molecular sieve bed (22) will cause the
22 second molecular sieve bed (22) to contain an optimized amount of oxygen and
23 pressure energy before the second molecular sieve bed (22) enters the adsorption
24 phase. Such a design can concentrate the separated oxygen to improve

1 performance of producing oxygen for the oxygen concentrator.

2 With reference to Figs. 2 and 5, the next step is to further rotate the cams

3 (113) to an angle of 195° related to the initial positions, and the pressure

4 conditions in the molecular sieve beds (21, 22) and the oxygen storage bed (23)

5 are indicated by a line 5 shown in Fig. 2. The second valve (132) is now closed,

6 and instead the fourth valve (134) is opened, but the third valve (133) is still open.

7 At this moment, a small amount of the purified oxygen in the first molecular

8 sieve bed (21), a small amount of the oxygen-rich product in the oxygen storage

9 bed (23) and the compressed air caused by the compressed air source (103) come

10 simultaneously into the second molecular sieve bed (22) to pressurize rapidly the

11 same. Now, the pressurized second molecular sieve bed (22) is still in the

12 aforesaid balance phase, but is approaching the end of this balance phase. The

13 rapidly increased pressure in the second molecular sieve bed (22) will enhance

14 efficiently the performance of producing the oxygen.

15 With reference to Figs. 2 and 6, the next step is to further rotate the cams

16 (113) to an angle of 270° related to the initial positions, and the pressure

17 conditions in the molecular sieve beds (21, 22) and the oxygen storage bed (23)

18 are indicated by a line 6 shown in Fig. 2. Likewise, the third valve (133) is now

19 closed, and instead the first valve (131) is opened to allow the first molecular

20 sieve bed (21) to communicate with the atmosphere. The compressed air comes

21 continuously into the second molecular sieve bed (22) that is going to become

22 the adsorption phase. The nitrogen of the incoming compressed air is trapped by

23 the molecular sieve material in the second molecular sieve bed (22) while the

24 oxygen of the incoming compressed air is allowed flow through as previously

1 described.

2 Meanwhile, a small amount of the purified oxygen in the second
3 molecular sieve bed (22) is directed into the oxygen storage bed (23) to become
4 the oxygen-rich product. Since the first molecular sieve bed (21) is
5 communicated with the atmosphere, the pressure in the first molecular sieve bed
6 (21) is going to be equalized with the atmospheric pressure that means the first
7 molecular sieve bed (21) is changed to the desorption phase. The trapped
8 nitrogen will be released or desorbed by the molecular sieve material in the first
9 molecular sieve bed (21) as the pressure is falling. Also, a small amount of the
10 oxygen-rich product in the oxygen storage bed (23) is redirected into the first
11 molecular sieve bed (21) to purge the first molecular sieve bed (21) because of
12 the pressure difference. The released nitrogen is mixed with the oxygen-rich
13 product, and the mixture is eventually exhausted into the atmosphere as
14 previously described. Therefore, the molecular sieve material in the first
15 molecular sieve bed (21) is revived to have a capability of trapping the nitrogen.

16 In effect, the pressure conditions of the first and the second molecular
17 sieve beds (21, 22) shown in the Figs. 3 and 6 are converse actions. The pressure
18 conditions of the first molecular sieve bed (21) illustrated in Fig. 3 are initially
19 maintained in the adsorption phase, but are switched to enter into the desorption
20 phase illustrated in Fig. 6. Likewise, the pressure conditions of the second
21 molecular sieve bed (22) illustrated in Fig. 3 are initially maintained in the
22 desorption phase, but are switched to enter the adsorption phase illustrated in Fig.
23 6. The alternate changes of the pressure conditions between the two molecular
24 sieve beds (21, 22) cause the oxygen contractor to produce repeatedly the

1 oxygen.

2 With reference to Figs. 2 and 7, the next step is to further rotate the cams
3 (113) to an angle of 345° related to the initial positions, and the pressure
4 conditions in the two molecular sieve beds (21, 22) and the oxygen storage bed
5 (23) are indicated by a line 7 shown in Fig. 2. The third and the fourth valves
6 (133, 134) are opened, and other cam-actuated valves are closed. However, the
7 pressure conditions in the molecular sieve beds (21, 22) illustrated in Fig. 7 are
8 just a converse action of the pressure conditions in the molecular sieve beds (21,
9 22) illustrated in Fig. 4.

10 With reference to Figs. 2 and 8, the next step is to further rotate the cams
11 (113) to complete a revolution and over an angle of 15° related to the initial
12 positions, and the pressure conditions in the molecular sieve beds (21, 22) and
13 the oxygen storage bed (23) are indicated by a line 8 shown in Fig. 2. The second
14 and the third valves (132, 133) are opened, and other cam-actuated valves are
15 closed. However, the pressure conditions in the molecular sieve beds (21, 22)
16 illustrated in Fig. 8 are just a converse action of the pressure conditions in the
17 molecular sieve beds (21, 22) illustrated in Fig. 5.

18 Since the cam-actuated flow control valves are actuated to be opened
19 and closed, the timing of pressurization that introduces compressed air into the
20 molecular sieve beds (21, 22) can be precisely controlled. Also, the pressure
21 conditions of the three beds (21, 22, 23) can be switched timely. A smaller
22 amount of the molecular sieve materials is required to produce the concentrated
23 oxygen than prior art. With a smaller amount of the molecular sieve materials is
24 needed than the prior art, the oxygen concentrator can be fabricated with a

1 compact size to reduce the manufacturing cost and weight of the oxygen
2 concentrator. In addition, since the cam-actuated flow control valves change
3 gradually their position to different ways, the noise generated is smaller so that
4 the oxygen concentrator is quiet.

5 Even though numerous characteristics and advantages of the present
6 invention have been set forth in the foregoing description, together with details
7 of the structure and function of the invention, the disclosure is illustrative only,
8 and changes may be made in detail, especially in matters of shape, size, and
9 arrangement of parts within the scope of the appended claims.